Question 1:

The industrial plant shown in Figure 1 consists of two three-phase, star connected motors connected in parallel and fed from a feeder of capacity 250 A per phase and a negligible impedance. The first motor absorbs 240 KW at a lagging power factor of 0.8; the second motor absorbs 140 KVA at a lagging power factor of 0.85. The supply voltage is $680\sqrt{3}$ volt (line to line, *RMS*).

a) Determine the value of the system power factor, active, reactive and apparent powers.
b) If the plant is to expand by adding a new three-phase, delta connected motor that absorbs 100 KVA at a lagging power factor of 0.8. Can this load be added without exceeding the feeder capacity?
c) Calculate the active and reactive powers of the 3-phase star-connected load to be added to make the system total consumed power equal to 450KW while making the system power factor equal to 0.95 lagging?

[10+5+10=25 marks]

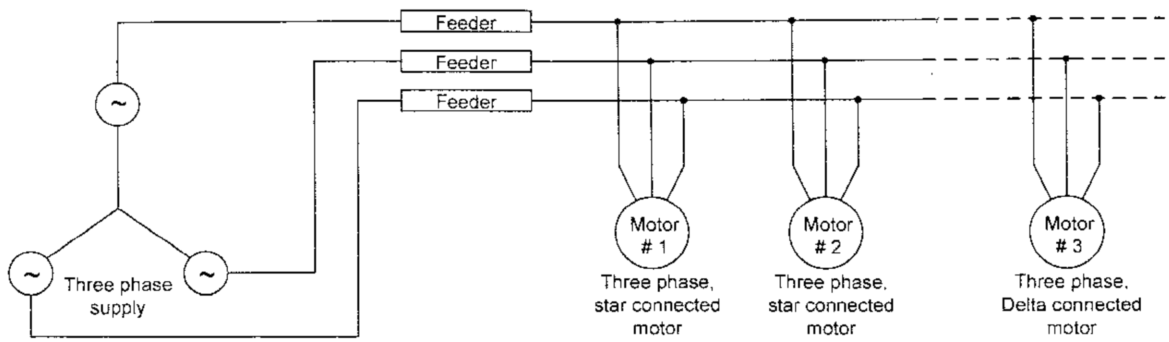

Figure 1

(a) $V_L = 680\sqrt{3}$

$V_{ph} = \frac{V_L}{\sqrt{3}} = 680 \angle$

Motor ①

0.8

$\phi = \cos^{-1}(0.8)$

$\phi = 36.86°$

$\tan\theta = \frac{Q}{P}$

$Q = P \tan\phi$

$Q = 240k \tan(36.86°)$

$Q = 21$ [illegible] VAR

Motor ②

$S = 140$ kVA

$\phi = \cos^{-1}(0.85) = 31.78°$

$P = 140kVA (0.85)$

$Q = 140kVA \sin(31.78°)$

$P_2 = 119\,000$ W

$Q_2 = 73\,732.27$ VAR

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$\Rightarrow$ $P_T = P_1 + P_2 = (240K) + (110K) = 359$ KW

$Q_T = Q_1 + Q_2 = 72936.57 + 21257.02 = 94,059.35$ VAR

$S = \sqrt{P_T^2 + Q_T^2} = 371,346.5$ VA

Source PF = $\frac{P}{S} = 0.966$

③ 150 KVA 0.8 lag $I_{motor} = 250$ A

Motor ①
Current Drawn $V_L = 680\sqrt{3}$

$P = \sqrt{3} V_L I_L \cos(\theta)$

$240K = \sqrt{3}(680\sqrt{3}) I_L (0.8)$

$I_L = \frac{240K}{3(680)(0.8)} = 147.0$ A

Motor ②
Current Drawn

140 KVA $= V_L I_L$

$I_L = \frac{140 KVA}{680\sqrt{3}} = 118.86$ A

Motor ③
100 KVA 0.9 lag

100 KVA $= V_L I_3$

$I_3 = \frac{100K}{680\sqrt{3}} = 84.90$ A

$\therefore I_T = I_1 + I_2 + I_3 = 147 + 118 + 84.9$

$I_T = 350.7$ A

∴ Motor cannot be added within the limits capacity

$\longrightarrow$
See back

Question 2:

The magnetic circuit shown in figure 2 has an infinitely permeable magnetic core. The following are given:

$g_1 = 5mm$	$A_1 = 5cm^2$	$N_1 = 80\ turns$
$g_2 = 5mm$	$A_2 = 5cm^2$	$N_2 = 100\ turns$
$g_3 = 10mm$	$A_3 = 10cm^2$	$N_3 = 125\ turns$

The three coils in the circuit are excited simultaneously such that $I_1 = 12A$, $I_2 = 10A$ and $I_3 = 8A$, with the direction of the currents as shown. Determine:

a. The flux density in the air gap g_1.
b. The flux linkage and the self-inductance of coil #2.
c. If $I_1 = 10A$, and $I_2 = 10A$, what should be the direction and value of the current I_3 in order to bring the flux at N_2 to zero?

[7+6+7=20 marks]

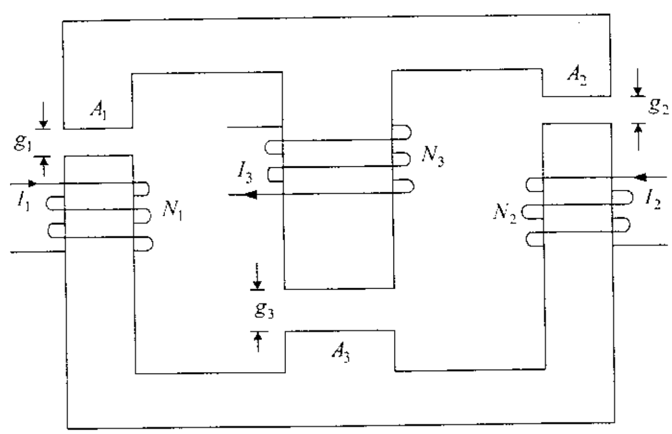
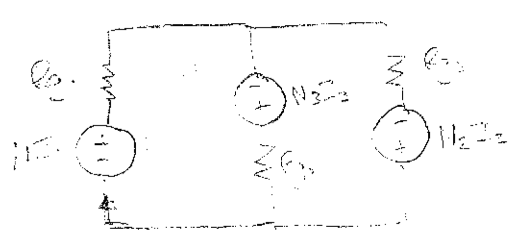


Figure 2



$-N_1I_1 - N_2I_2 = (2R_c)\phi_1 - R_c\phi_2$

$\Rightarrow 2(N_3I_3 - N_2I_2) = 3R_c\phi_2 + 2(\ldots)\phi_2$

$-N_1I_1 + N_2I_2 \cdot 2N_3I_3 = 3R_c\phi_2$

$\phi_2 = \frac{-N_1I_1 + N_2I_2 + 2N_3I_3}{3R_c}$

$\phi_2 = \frac{-(80)(2) + (100)(\ldots) + 2(\ldots)(8)}{3(\ldots)}$

$\phi_2 = 0.256 \text{ mWb}$

$\phi_1 = \frac{-N_1I_1 - N_2I_2 + R_c\phi_2}{2R_c}$

$= \frac{-80(\ldots) - (100)(\ldots) + (\ldots)}{\ldots}$

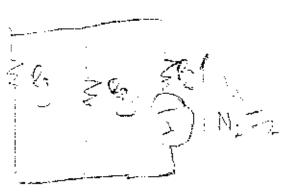
$\phi_1 = 4.84 \ \mu\text{Wb}$

$B = \frac{\phi}{A} = \frac{4.84 \ \mu\text{Wb}}{(5\text{cm}^2)(10^{-4})} = 9.69 \text{ mWb/m}^2$

(3) Flux linkage $= N\phi_2 = (100)(8.33 \times 10^{-5}) = 8.33 \times 10^{-3} \text{ Wb}\cdot\text{T}$

Self inductance is equal to: $L = \frac{N_2\phi_2}{I_2}$

Now $I_1 = 0$, $I_3 = 0$



$R_{eq} = \frac{1}{2}R_c + R_c = 1193662.0 \ \Omega$

$F = NI = R\phi_2$

$\phi_2 = \frac{NI}{R_{eq}} = \frac{(100)(1\text{A})}{1193662.0} = 8.38 \times 10^{-5} \text{ Wb}$

$L = \frac{N_2\phi_2}{I_2} = \frac{(100)(8.38 \times 10^{-5})}{10} = 8.38 \times 10^{-4} \text{ H}$

$= 0.838 \text{ mH}$

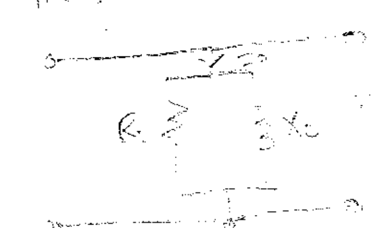
Question 3:

A 50 KVA, 600/2400 V, 60 Hz, single-phase transformer has open circuit and short circuit test data as follows:

	Volt [V]	Current [A]	Power [W]
Open circuit test	600	3.34	484
Short circuit test	76.4	15.0	392.0

a. Find the parameters of the **approximate** equivalent circuit referred to the primary side.
b. If this transformer is used as a step up transformer supplying 90% load at 0.8 PF lagging find:
   1. The input voltage.
   2. The voltage regulation.
   3. The transformer efficiency.
   4. Draw the vector diagram representing this load.
c. Find the load level at which maximum efficiency occurs.
d. Assume that the load power factor is varied while the load current and the secondary terminal voltage are kept constant. Determine the load power factor for maximum regulation and the value of this regulation

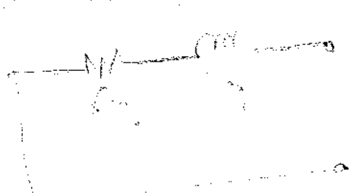
[10+14+3+8=35 marks]



$P = VI\cos(\phi)$

$= 0.24$

$\phi = 76°$



$Z = \frac{V}{I}$ $= 5.09$

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Question 4:

Chose the correct answer (10 questions in total):

[20 marks]

1) If two circuits (a 3-phase and a 1-phase) are delivering the same power at the same voltage level:
   a) The losses of the two circuits will be the same
   b) The current in the single phase circuit will be one third of the three-phase current.
   c) The copper loss in the single-phase is six times the three-phase given the two systems use the same conductor sizes.
   d) The single-phase circuit will use more copper weight.

2) Magnetic materials are preferred over non-magnetic materials for the machine design because:
   a) It is lighter in weight
   b) It can withstand more voltage levels
   c) It provide lower resistance to the flow of magnetic flux
   d) It has lower permeability than non-magnetic materials.

3) Eddy current losses in Transformers is due to:
   a) The vibration of the transformer
   b) The current passing in the winding
   c) The variable flux in the core
   d) The presence of two separate electric winding.

4) Laminations are used to reduce the eddy current losses by:
   a) Reducing the magnetic circuit resistance.
   b) Reducing the magnetic circuit reluctance.
   c) Reducing the magnetic circuit effective length.
   d) Reducing the induced emf.

5) Which value represents the best voltage regulation:
   a) + 5%
   b) – 5%
   c) + 10%
   d) Zero

6) Which of these statements is true:
   a) The transformer can operate as a step-up or step-down transformer only with inductive loads.
   b) The transformer turns ratio determines the operating voltages for both primary and secondary winding at any loading level.
   c) The transformer voltage per turn is almost equal for both primary and secondary windings.
   d) The transformer magnetizing current depends mainly on the loading level.

7) Which of these statements is true:
   a) The transformer core losses depend mainly on the frequency, the lamination thickness, the flux and the load type.
   b) The transformer voltage regulation can be improved by reducing the loading level, supplying unity power factor loads or increasing the flux.
   c) The transformer short circuit test is normally conducted on the LV terminals at rated voltage.
   d) The transformer output voltage depends on the loading level, power factor and device parameters.

8) The transformer can achieve zero voltage regulation at:
   a) Unity power factor loads.
   b) Only at full load.
   c) If it is loaded with capacitive load.
   d) Not possible at any loading condition.

9) The voltage per turn in the transformer windings:
   a) Is based on the transformer turns ratio.
   b) Is the same in both primary and secondary.
   c) Is larger in the primary than the secondary.
   d) Is larger in the secondary than the primary.

10) The no load test in transformers should be conducted:
   a) In high voltage side while low voltage is open.
   b) In high voltage side while low voltage is loaded.
   c) In low voltage side while high voltage is open.
   d) In low voltage side while high voltage is loaded.